

No.	Mag.	Mean R.A.			Mean N.P.D.	
		1877, Jan. 1.			1877, Jan. 1.	
		h	m	s	°	'
586	7	23	29	40	99	27
617	5		31	17	103	45
619	8		31	22	100	40
629	7	23	31	52	99	19

Royal Observatory, Greenwich,
1875, Nov. 12.

*Spectroscopic Observations made at the Royal Observatory,
Greenwich.*

(Communicated by the Astronomer Royal.)

Since the establishment of the new Physical Department, the Spectroscope has been used, as opportunity offered, for the determination of the motions of stars in the direction of the visual ray, by means of the displacement of the lines of known terrestrial elements in their spectra, the line usually selected being the bluish-green line of hydrogen, corresponding to the F line of the solar spectrum. Originally the comparison between the line of hydrogen and that in the star's spectrum was made by means of a vacuum-tube placed within the tube of the Equatoreal, and at a distance of either 2 feet or 4 feet from the slit of the spectroscope, the vacuum-tube being carefully adjusted to pass through the axis of the cone of rays from the object-glass, and at right angles to it; the observation was made with the tube parallel to the slit of the spectroscope in some cases, and at right angles to it in others. A convex cylindrical lens has sometimes been used in front of the slit, to give greater breadth to the star's spectrum, though the cylindricity of the prisms themselves has usually been found sufficient for this purpose.

On 1874, August 24, two concave lenses, placed side by side, were substituted for the single concave lens in the collimator-telescope, so that the rays which returned through the collimator to the eye of the observer (after reflection from the last prism of the train used) passed through a different concave lens from that on which the incident-pencil fell. The results obtained with this arrangement appeared to be affected by a systematic error, and in consequence of this the original plan was reverted to on 1875, March 4. Suspicion being thus thrown on the method of comparison adopted (in which a narrow strip of the object-glass was used for the rays from the vacuum-tube and the rest for the rays from the star) it was abandoned, and an actual

image of the comparison-light formed on the slit immediately above and below that of the star, by means of two comparison-prisms in connection with a collimating lens, great care being taken that the cone of rays filled the whole object-glass. This method has been used regularly since 1875, May 31, the position of the image of the comparison-light on the slit having been in every case carefully adjusted before the observation. Originally the relative displacement of the star line was measured by means of the slow-motion screw acting on the train of prisms, the line being brought up to a fixed point in the field of view; but on account of the uncertainty of this method, arising from loss of time in the action of the screw (though care was taken that the weight of the prisms always acted in the same direction), a new micrometer was applied on 1874, November 27, and has been used regularly since that date.

Besides the micrometer measures, the displacement of the star line has also been estimated in terms of the width of the comparison line of hydrogen, the width of the slit being also noted, and the displacement in wave-length inferred from micrometer measures of the width of the hydrogen line under similar conditions. The width of the slit has been varied as much as possible, in order to make these estimates independent of any bias from previous results. With a view to the elimination of systematic errors as far as possible, the dispersive power has been varied as much as circumstances would allow. For a dispersive power of two prisms, the train used consists of two half-prisms, the second of which is silvered on the back, so as to reflect the rays directly back through the collimator, where they are viewed by means of a diagonal prism placed close to and on one side of the slit. The magnifying power used in this case was 37. The dispersive powers of $1\frac{1}{2}$, $2\frac{1}{2}$, and $3\frac{1}{2}$ prisms are given by a train commencing with a half-prism, followed by one or more whole prisms, the spectrum being viewed by a second telescope, as in ordinary spectroscopes. The small telescope has a magnifying power of 19. All the prisms are compound.

Whenever practicable, the star line has been compared directly with the $H\beta$ line, and the relative displacement estimated. Where this could not be done, the star line was bisected by the pointer (or thick cross-wires), and the $H\beta$ line then compared directly with the pointer before the micrometer screw was touched. The observation being necessarily made in a dark field, it was sometimes very difficult to see the pointer and star line distinctly together, and some of the measures are consequently very discordant, especially where the star line is broad and nebulous, as in the case of *Altair*, the observations of which star are entitled to very little weight.

The measures since 1875, May 31, are the most reliable, the mode of comparison being apparently free from any possible systematic error, except what might arise from the lines being "winged" through fault in the surfaces of the prisms, a

defect which would affect a bright line, and an absorption or dark line, differently. If practicable, it would be desirable to compare the star line with the absorption line of hydrogen, as seen on a continuous spectrum.

Since 1875, May 31, the astigmatism produced by the prisms has been corrected by a convex cylindrical lens, placed within the collimator, and near the slit, a convex cylindrical lens being also used in front of the slit to give breadth to the star spectrum.

The concluded motions given in the following table have been inferred from the observed displacements, after correcting for the Earth's motion, resolved in the direction of the star; the method used being the same as that adopted by Mr. Huggins in his researches on stellar motions. The velocity of light is taken as 185,000 miles a second.

MOTIONS OF STARS IN THE LINE OF SIGHT, IN MILES PER SECOND.

(+ denotes recession; - approach.)

The observations prior to 1875, May 31, are not considered reliable; those between 1874, August 24, and 1875, March 3, are probably affected by large instrumental error.

Date.	Observer.	No. of Prisms.	Earth's Motion in miles per second.	Concluded Motion of Star. Measured.	Estimated.	Remarks.
1874	July 17	2	+ 2	- 104	...	Not very certain. Star line very ill defined.
	21	2	+ 2	- 145	- 147	In each case, after bisection, the H β line was seen its own width on the red side of the star line.
	Aug. 3	2	+ 4	- 94	- 67	
1875	11	2	+ 5	- 27	- 62	
	June 25	2	- 2	- 48	- 25	
	26	2	- 1	- 16	- 19	Everything in good adjustment.
	July 8	2	- 0	- 39	- 14	
	12	2	+ 1	- 47	- 66	Definition good. Direct comparison.
	29	1½	+ 3	- 38	- 39	Direct comparison.
	31	1½	+ 3	- 54	- 47	Very bright indeed. Direct comparison.
Aug. 30	M.	2½	+ 7	- 50	- 34	Sky hazy. Line only seen occasionally.
Sept. 3	M.	3½	+ 7	- 29	- 24	Line broad and nebulous, and not very distinctly seen. Indirect comparison.

Vega.

Arcturus.

1874 Aug. 6 W. C. 2 + 14 - 114 - 96 Star low. Lines hard to see. Observation very uncertain.
Compared with Magnesium.

Altair.

1874 Aug. 6 W. C. 2 + 4 + 76 + 54 Observations fair at first; afterwards, difficult, through haze.
11 W. C. 2 + 5 + 68 + 75 Everything in good adjustment.
1875 June 26 W. C. 2 - 7 - 102 - 26 Line in star not well seen.
July 8 M. 2 - 4 - 58 - 24 Direct comparison doubtful. Star line faint, ill defined, and broad.
12 M. 1½ - 3 + 106 + 85 Star line very faint. Indirect comparison.
29 M. 1½ + 2 - 81 - 77 Indirect comparison.
31 M. 2½ + 2 + 14 + 21 Direct comparison showed the star line almost coincident with
31 M. 1½ + 2 - 22 that of hydrogen.
Aug. 4 M. 1½ + 3 - 87 Direct comparison.
30 M. 2½ + 10 - 61 Indirect comparison.

α Andromedæ.

1874 Nov. 4 M. 2 + 8 - 125 - 161 Definition bad.
Dec. 7 M. 2 + 15 + 79 ... Spectrum faint. Haze rising. Lines nearly coincident.
1875 July 29 M. 1½ - 15 - 15 Lines apparently very nearly coincident. Indirect comparison.
Aug. 4 M. 1½ - 14 - 7 Cloudy. Image faint and tremulous.
30 M. 1½ - 9 - 29

MOTIONS OF STARS IN THE LINE OF SIGHT, IN MILES PER SECOND.—(continued).

Date.	Observer.	No. of Prisms	Earth's Motion in miles per second.	Concluded Motion of Star. Measured.	Estimated.	Remarks.
<i>Capella.</i>						
1874 Dec. 4	M.	2	- 2	- 72	...	
14	M.	2	+ 1	- 49	...	Star line broad. Hydrogen line not well defined.
1875 Jan. 22	M.	2	+ 12	- 125	- 68	Star faint. Night hazy. Direct comparison.
<i>β Aurige.</i>						
1874 Dec. 14	M.	2	- 2	- 25	- 50	Spectrum faint.
<i>Sirius.</i>						
1875 Jan. 18	M.	2	+ 4	- 140	- 327	Wind high; frequent clouds. Star never long on slit. Width of slit doubtful.
20	M.	2	+ 5	- 96	- 59	
31	W. C.	2	+ 7	- 282	- 109	Star line hardly visible, and seldom seen. Observation doubtful.
Feb. 1	M.	2	+ 7	- 95	- 88	
Mar. 4	W. C.	2	+ 13	...	...	Star line seen distinctly on the red side of the hydrogen line.
9	W. C.	2	+ 13	+ 34	+ 40	Star line not well seen. Observation very uncertain.
10	M.	2	+ 13	+ 55	- 1	

Nov. 1875.

the Royal Observatory, Greenwich.

33

<i>Procyon.</i>							
1875	Mar. 6	M.	2	+ 14	- 40	- 30	Star line and hydrogen line nearly coincident.
	9	W. C.	2	+ 15	- 40	...	Star line and hydrogen line not seen together. Displacement doubtful.
<i>Castor.</i>							
1875	Mar. 10	M.	2	+ 16	+ 7	...	
<i>Regulus.</i>							
1875	Mar. 10	M.	2	+ 10	- 38	...	
	May 31	M.	2	+ 17	- 44	...	Image very unsteady. Star line faint at best, and often invisible. Bisection difficult and doubtful.
<i>γ Ursæ Majoris.</i>							
1875	May 31	M.	2	+ 12	+ 62	...	
<i>η Ursæ Majoris.</i>							
1875	June 11	M.	2	+ 10	+ 37	...	Star line very faint, and not often seen. Readings somewhat uncertain.
	.25	M.	2	+ 10	- 65	- 102	Star line scarcely visible when compared directly with H β .
	July 12	M.	2	+ 9	- 44	- 23	Star line very faint. H β line evidently <i>on</i> star line, which was much the broader, and not far from the centre. Uncertain.
<i>α Coronæ.</i>							
1875	June 25	M.	2	+ 10	- 119	- 31	Star line dark, and very broad and nebulous. The two lines were not seen together.

MOTIONS OF STARS IN MILES PER SECOND (*concluded*).

α Ophiuchi.

Date.	Observer.	No. of Prisms.	Earth's Motion in miles per second.	Concluded motion of Star. Measured. Estimated.	Remarks.
1875 June 25	M.	2	+ 3	— 26	Faint. Lines nearly coincident. Indirect comparison.
July 12	M.	1½	+ 7	+ 154	Faint. Not very well seen. Indirect comparison.

α Cygni.

1875 July 29	M.	1½	— 4	+ 58	Star line somewhat faint. Indirect comparison.
31	M.	1½	— 4	— 70	Indirect comparison.
Aug. 2	M.	1½	— 4	— 53	Indirect comparison.
30	{	1½	+ 1	— 32	Indirect comparison.
		2½	+ 1	— 21	Lines sensibly coincident.
				...	

α Pegasi.

1875 July 29	M.	1½	— 12	— 10	Star line broad and dark. Lines very nearly coincident.
Aug. 4	M.	1½	— 11	— 20	Indirect comparison.
30	M.	1½	— 4	— 66	Indirect comparison.

The results given are the means of the individual measures on the several nights of observation.
The initials W. C. and M. are those of Mr. Christie and Mr. Maunder respectively.

The following measures of lines in the spectra of *Aldebaran*, *Virginis*, and *Mars*, have been made by Mr. Maunder with the old star spectroscope, which has a single large prism of flint of 60°.

DARK LINES IN STELLAR SPECTRA.

Small Star Spectroscope.

The Wave-lengths are inferred from measurements of the principal Fraunhofer lines, made on 1875, April 7, combined with measures of the bright lines of certain elements given below.

Aldebaran.

1874, Nov. 24.

Micrometer. Rev.	Intensity.	Wave-length. Tenth-metres.	Elements.
49·227	4	5890	Sodium.
48·308	2	5840	
46·980	2	5755	Iron.
44·708	1	5575	Iron.
40·984	2	5440	Iron.
39·158	2	5340	Iron.
38·749	3	5320	Iron.
37·895	4	5280	Iron.

1874, Dec. 2.

Micrometer. Rev.	Intensity.	Wave-length. Tenth-metres.	Elements.
37·372		5170	Magnesium.
32·789		4990	Air.
50·737		5870	Sodium.

1874, Dec. 2.

Measures of Bright Lines from Spectra of Elements, for comparison,
made at the same time as above.

Micrometer. Rev.	Assumed Wave-length. Tenth-metres.	Elements.
15·544	4480	Magnesium.
29·253	4861	Hydrogen H β .
36·935	5167	Magnesium (b_4).
37·267	5183	Magnesium (b_1).
32·815	5005	Air.
50·872	5892	Sodium (D).

The assumed Wave-lengths are taken from Watts' *Index of Spectra*.

Micrometer A used throughout.

δ Virginis.

1875, April 13.

This Spectrum is crossed by seven dark bands which shade off on the red side, and have the appearance of being composed of a number of fine lines. The bands are numbered from the red.

No. of Band.	Micrometer. Rev.	Wave-length. Tenth-metres.	Remarks.
I.	...	...	Too faint to measure.
II.	...	...	Too faint to measure.
III.	27'939	5420	Sharp edge (on the violet side).
IV. 1st edge	31'690	5255	
2nd edge	32'646	5210	Very black.
V. Sharp edge	38'446	4960	Edge on the violet side.
VI. Sharp edge	44'204	4790	Edge on the violet side. Band faint.
VII.	...	...	Too faint to measure.

Assumed Wave-length.
Tenth-metres.

H α	11'000	6562	From vacuum tube for comparison.
H γ	41'719	4861	

Micrometer B used throughout.

DARK LINES IN SPECTRUM OF MARS.

Small Star Spectroscope.

1875, July 1.

Micrometer.	Wave-length.	Elements.	Remarks.
10'263	6560	Hydrogen	C line.
11'158	6465	Calcium	
13'742	6257	Iron	
14'225	6217	Titanium	
15'052	6153	Sodium or Air.	
18'210	5940	Air	Very dark line.
18'506	5923	Air	Dark line.
18'840	5900	Sodium	D ₁ line.
18'904	5895	Sodium	D ₂ line.
19'782	5835		Dark line.
23'274	5625	Iron	
24'475	5560	Air	
25'715	5495	Iron or Air	
29'282	5337	Iron	
29'927	5305	Iron	

Micrometer.	Wave-length.	Elements.	Remarks.
30.610	5270	Iron	
31.484	5230	Iron	
31.945	5205	Chromium	
32.503	5183	Magnesium	b ₁ line.
32.802	5170	Magnesium	b ₂ line.
32.922	5165	Magnesium	b ₄ line.

Micrometer B used throughout.
Image tremulous.

The part of the Spectrum, lying southwards from its centre, for one-third of the breadth of the Spectrum was much fainter than the rest. The slit was narrow, and lay north and south.

Besides observations of prominences, the following measures of the widths of some of the Fraunhofer lines have been made by Mr. Christie with the powerful spectroscope which Mr. Spottiswoode kindly lent during the adjustment of the Observatory spectroscope.

MEASURES OF THE WIDTH OF FRAUNHOFER LINES.

Taken with the Spottiswoode Spectroscope.

1875, September 16.

Line.	Measured Width. Rev.	Wave-length corresponding to 1 Rev. Tenth-metres.	Width in Wave-length. Tenth-metres.	Remarks.
C	0.167	6.38	1.065	
D ₁	0.077	4.31	0.332	D ₂ was to the eye broader and more nebulous than D ₁
D ₂	0.116	4.31	0.500	
b ₁	0.057	2.91	0.166	b ₁ seemed a thin line in the middle of a haze.
Haze	0.533	2.91	1.551	
b ₂	0.220	2.91	0.640	
b ₃	0.068	2.91	0.198	Two lines: a black line on the re side, and a faint nebulous line the blue.
b ₄	0.200	2.91	0.582	
F	0.518	2.19	1.134	

Width of Slit = 0.001 inch.

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